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Sensor Systems Testbed for Telerobotic Navigation

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1. Abstract

A testbed has been developed for the study of sensor systems to be used in telerobotic operations. The program, conducted in conjunction with Johnson Space Center of NASA, addresses the navigational problems associated with target acquisition and rendezvous for teleoperated robotic work stations. The program will utilize a mobile platform which will support various sensor systems during their development and testing in an earth-based environment.

2. Introduction

The testbed has been developed in support of a program to develop sensor systems that will aid in rendezvous and docking operations to be conducted as a part of the space station program. A mobile platform has been used to permit testing of these components in a conventional laboratory environment with consequent savings in cost and complexity. The sensor systems, while representative of devices currently in use for robotic applications, are not considered prototypical of the ones that will be used in the final applications. The test program provided information that will support the design of system augmentations and will lead to a comprehensive test program for sensor development.

3. System Description

The platform selected for this program, as shown in figure 1, is an electrically driven system utilizing three wheels which are steerable in a coordinated manner. It is capable of rapid changes in direction as well as turning in place. The internal control computer is capable of accepting commands to respond in real time to joy stick motion or to traverse a preselected path under program control. The commands are generated utilizing a host computer and transmitted over a radio frequency (RF) modem link.

The sensor systems address the problems of target acquisition, path planning and obstacle avoidance, and guidance. The systems are used in a teleoperated mode for the initial phases of the program with autonomous tests being planned for later in the program. The testbed has been equipped with an initial configuration of sensors and other components will be introduced at a later date.

The primary target acquisition system utilizes a video camera to permit target recognition and to provide azimuth and elevation information. The camera, as shown in figure 2, has automatic focusing and a variable focal length lens, so that target search can be performed in the wide angle mode and target tracking can be performed in the telephoto mode. A laser ranging device, shown in figure 3, is used to provide range information. The video camera and range units are mounted on a pan unit to facilitate the search function.

Obstacle avoidance is provided by a mapping sensor and an impact detection sensor. The mapping sensor, shown in figure 4, utilizes a commercially available ultrasonic transducer which is scanned over the full range of azimuth to simulate a radar mapping of the environment. The ultrasonic transducer is mounted so that it is facing down to a metal reflector, set at 45 degrees, which redirects the acoustic wave in a horizontal plane. The metal reflector is rotated by a stepping motor to provide the scanning function. A conventional radar system was not used for reasons of operational convenience, but the similarity in wavelength between ultrasound and microwaves should result in comparable resolution between the two transducer concepts. An impact detection system in the form of a skirt that surrounds the unit may be seen in figure 1. The sensors are small PVDF film elements attached to the circumferential band. These elements flex when the skirt impacts an obstacle and generate a small piezoelectric voltage which is amplified and detected.

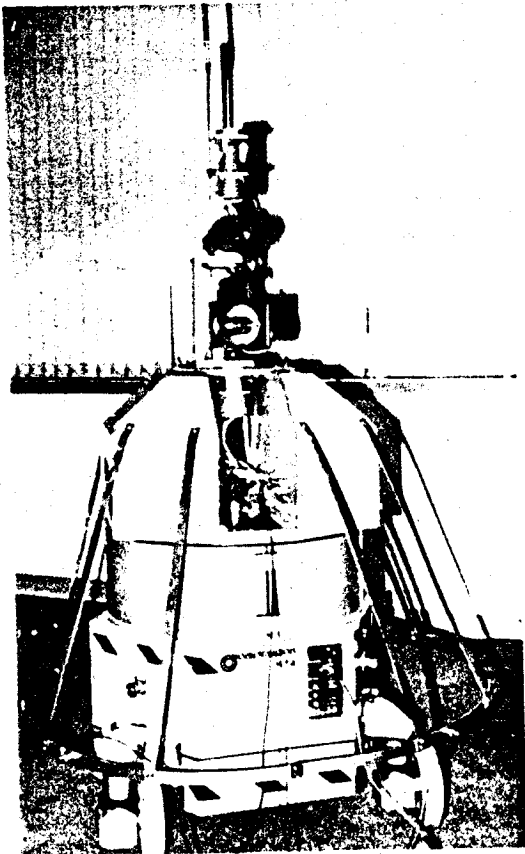


Figure 1
Mobile platform with sensors

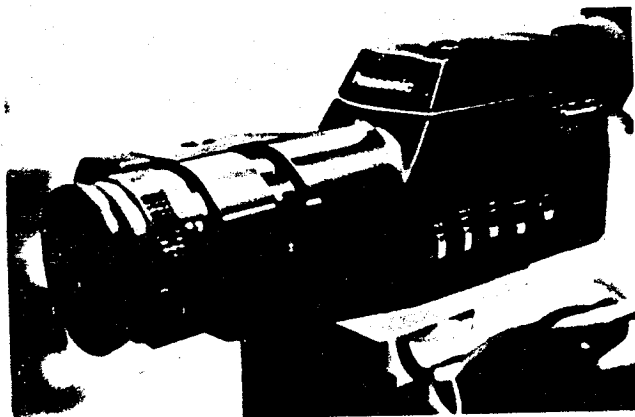


Figure 2
Video camera

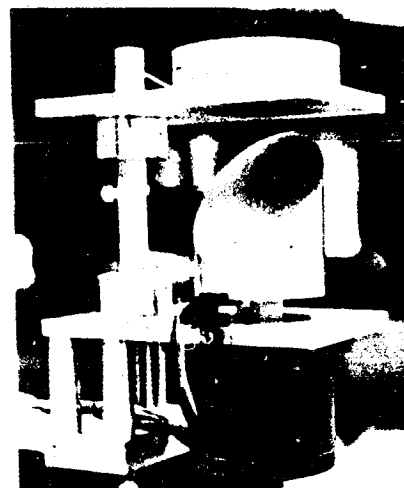


Figure 4
Acoustic mapping sensor

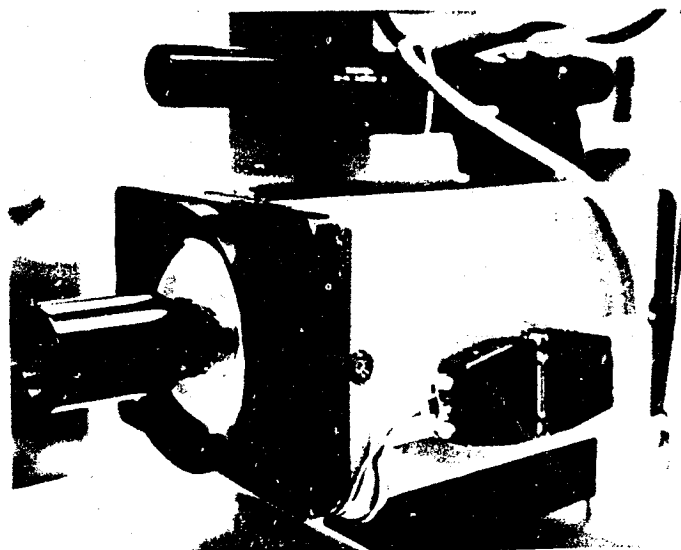


Figure 3
Laser rangefinder

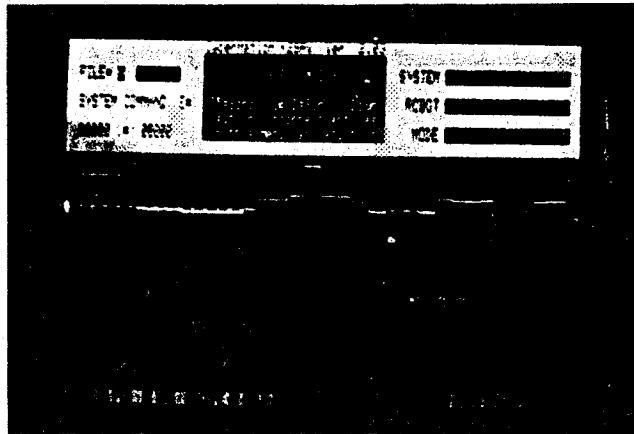


Figure 5
Monitor display

The data from the range, mapping, and impact sensors are interfaced to a microprocessor which controls, formats, and transmits the data to the host computer. The data is transmitted over the same RF modem as is used for the control commands of the platform. The presentation of the data on the monitor of the host computer is done using the available software in its resident system. A typical display is shown in figure 5. The acoustic range data is shown in graphical form with azimuth angle and range plotted on the same display. Parameters such as laser range, camera and laser azimuth angle, and acoustic range in the forward direction are displayed as digital values. The control of the platform is provided by a joystick at the workstation or through navigational instructions from the host computer.

4. Test Program

A test program has been carried out at the Johnson Space Center to evaluate the effectiveness of the sensors provided for navigation. The tests included operation in sight of the operator, operation using only the sensors, navigation around an obstacle and down a corridor, and rendezvous with a target. It was found that operation in an environment free of obstacles was easily accomplished using vision and range as the primary sensors. When obstacles requiring intricate maneuvers for their avoidance were introduced, the problem became more difficult. Real-time mapping of the space around the platform with an easily viewed display is required for navigation in this environment.

The vision system was by far the most important sensor. Augmentation of this capability by the use of multiple cameras to give panoramic coverage to simulate the capability of human vision would be desired. The test environment did not simulate the lighting conditions of a space environment and consideration should be given to that aspect.

The range information was not readily accessible to the operator as he viewed the video monitor. An improved presentation of this data would be quite valuable. In lieu of this information, a stereo vision type of display could be considered.

The panning mechanism for the video and laser rangefinder units did little to improve the utility of the system. The ability of the platform to pivot in place using its own drive system was a far more valuable mechanism, since you could drive off in the direction that you were viewing at any time.

The mapping system was limited by the same consideration as the range system, lack of adequate display. The resident software in the host did not provide for a conventional range-azimuth display. One of our recommendations was to separate the sensor system from the host control system so that software for the display of the data could be developed separately. This change would also address a problem that was experienced with the RF link, that of contention and interference between the control and data acquisition functions.

It is our intent to continue development of sensor systems for this platform. Rockwell International has procured an identical platform for use in its Telerobotic Integration and Engineering Research Laboratory so that components may be evaluated prior to their testing at NASA.

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